BLOOD FLOW DYNAMICS IN MICROVESSEL BIFURCATIONS

MOHAMAD THARMIZI BIN MOHAMAD EHSAN

Thesis submitted is fulfilled of requirement
for the award of degree of
Bachelor of Mechanical Engineering

Faculty of mechanical engineering
UNIVERSITY MALAYSIA PAHANG

November 2009

SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

Signature
Name of Supervisor: MOHAMAD MAZWAN BIN MAHAT
Position: LECTURER
Date: 24 NOVEMBER 2009

STUDENT'S DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

Signature
Name: MOHAMAD THARMIZI BIN MOHAMAD EHSAN
ID Number: MA06055
Date: 24 NOVEMBER 2009

Dedicated to my parents

ACKNOWLEDGEMENTS

I am grateful and would like to express my sincere gratitude to my supervisor Mr Mohamad Mazwan Bin Mahat for his germinal ideas, invaluable guidance, continuous encouragement and constant support in making this research possible. He has always impressed me with his outstanding professional conduct, his strong conviction for science, and his belief that a degree program is only a start of a life-long learning experience. I appreciate his consistent support from the first day I applied to graduate program to these concluding moments. I am truly grateful for his progressive vision about my training in science, his tolerance of my naïve mistakes, and his commitment to my future career. I also sincerely thanks for the time spent proof reading and correcting my many mistakes.

My sincere thanks go to all my labmates and members of the staff of the Mechanical Engineering Department, UMP, who helped me in many ways and made my stay at UMP pleasant and unforgettable. Many special thanks go to member in my group research with the same supervisor for their excellent co-operation, inspirations and supports during this study.

I acknowledge my sincere indebtedness and gratitude to my parents for their love, dream and sacrifice throughout my life. I am also grateful to my fiance for her sacrifice, patience, and understanding that were inevitable to make this work possible. I cannot find the appropriate words that could properly describe my appreciation for their devotion, support and faith in my ability to attain my goals. Special thanks should be given to my committee members. I would like to acknowledge their comments and suggestions, which was crucial for the successful completion of this study.

ABSTRACT

This thesis deals with the blood flow behaviour in the microvessel bifurcation using variety of blood parameters. There are two situations for the analysis which normal mircovessel and abnormal microvessel bifurcations. The objectives of this thesis are to investigate the effect of bifurcation on blood flow distributions and predict flow abnormalities due to blood properties. The thesis describes the finite volume technique to predict the abnormalities and identify the effect of the bifurcation. The structural three-dimensional solid modeling of normal and abnormal blood vessel were developed using the computer-aided drawing software. The strategy of validation of finite volume model was developed. The finite volume analysis was then performed using COSMOS Flow in Solidwork software. From the result,it is observed that bifurcation give an effect to the blood flow behavior.For normal and abnormal case, using the different pressure for same diameter of blood vessel bifurcation, the pressure result shown an increment when blood flow into the bifurcation. It is same when analyze using different velocity for same diameter, the value will decrease when it goes to the bifurcation. For analysis using different diameter of blood vessel bifurcation, the effect of bifurcation will clearly seen. Pressure and velocity will be proportional in values of analysis refer to the equation of fluid dynamics. Peak velocity of the normal and abnormal also showed different values. Normal microvessel bifurcation has a higher value of peak velocity than abnormal microvessel bifurcation. Reynolds Number also get an effect when the diameter of the blood vessel increase. Finally, the correlations obtained from this numerical result could be used to investigate the pressure and velocity distribution around the diseased segment.

ABSTRAK

Tesis ini membentangkan tentang sifat darah pada salur darah yang bercabang dua menggunakan parameter darah yang berbeza.Terdapat dua situasi di dalam analisis ini iaitu salur darah bercabang normal dan juga salur darah bercabang tidak normal.Objektif tesis ini ialah untuk mengenalpasti kesan salur darah bercabang kepada pergerakan darah dan untuk menjangka pergerakan darah tidak normal berdasarkan sifat darah itu sendiri.Tesis ini membincangkan penilaian kebolehtahanan untuk menjangka sesuatu tidak normal dalam salur darah dan kesan cabang pada pergerakan serta sifat darah.Permodelan struktur tiga dimensi untuk salur darah normal dan tidak normal dibangunkan dengan perisian lukisan bantuan komputer.Strategi pengesahan model kelantangan terhingga dibangunkan.Analisis kelantangan terhingga dijalankan dengan COSMOS di dalam perisian Solidwork.Keputusan yang diperolehi daripada analisis ialah cabang pada salur darah memberi kesan kepada pergerakan dan sifat darah.Bagi kes salur darah normal dan tidak normal menggunakan tekanan yang berbeza tetapi diameter sama,nilai tekanan menunjukkan peningkatan apabila darah melalui cabang.Ia juga sama apabila analisis kelajuan darah berbeza pada diameter yang sama,ia menunjukkan penurunan apabila sampai ke salur darah yang bercabang.Bagi analisis untuk diameter salur darah yang berbeza,kesan disebabkan salur darah bercabang dapat kelihatan dengan jelas.Tekanan dan kelajuan adalah bertentangan antara satu sama lain merujuk kepada persamaan dalam dinamik berdalir.Kelajuan tertinggi darah turut memberi nilai yang berbeza dalam kes salur darah normal dan tidak normal.Salur darah normal mempunyai nilai kelajuan tertinggi lebih daripada salur darah tidak normal.Nombor Reynold juga menunjukkan kesan apabila diameter salur darah berubah.Perkaitan diperolehi daripada kajian ini boleh dimanfaatkan untuk lanjutan taburan tekanan dan kelajuan bagi darah disekitar tempat yang sakit.

TABLE OF CONTENTS

CHAPTER 2 : FLOW BEHAVIOR IN MICROVESSEL BIFURCATIONS

CHAPTER 3 : METHODOLOGY

CHAPTER 4 : RESULTS AND DISCUSSIONS

LIST OF TABLE

LIST OF FIGURES

LIST OF SYMBOLS

u_i	:	velocity in the ***i***-th direction
P	:	pressure
f_i	:	body force
μ_i	:	viscosity
δ_{ij}	:	Kronocker delta
ρ	:	density
υ	:	mean velocity
D	:	diameter
∂t	:	partial differential of time
∂p	:	partial differential of pressure
R	:	radius
L	:	length
α	:	alpha
A	:	area
V	:	volume

LIST OF ABBREVIATIONS

MCA	:	Middle cerebral artery
CFD	:	Computational Fluid Dynamics
CAD	:	Computer Aided Design
FEM	:	Finite Element Method
CT	:	Computer-assisted tomography
CAE	:	Computer Aided Engineering
CSS	:	Computational Solid Stress
FEA	:	Finite Element Analysis
PDE	:	Partial Differential Equation

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Currently many diseases have been detected by the doctor or researcher in the medical part. One of the main part in the body which mostly detected as the place to create a disease is at the micro vessel bifurcations. This micro vessel bifurcation is the place where the blood will be separated into two ways. The flow of the blood will going through the micro vessel bifurcations or as known as micro channel and sometimes something happen at that part. In our body have many micro channel especially in the lung, aorta, and brain. All this micro channel have a potential to be the reason why many disease happen in the body but we must thinking clearly that it must be have a reason on that.

This project concerns about the disease which can happen in the micro vessel bifurcation depend on the blood profile or parameter. What will happen if the pressure increases at that place or is the velocity of the blood will cause the disease at that part. In order to satisfy the main concern of this project, it will focus on the blood profile or parameter in the blood vessel and also at the micro vessel bifurcations. Currently many disease have been detected by the researcher in the medical field and also doctor at this part of blood vessel but still have unknown reason why it happen and how it can be like that. The results of this fluid dynamics analysis through numerical simulations are expected to explain this problem and help the people in medical to search the best treatment for the disease.

1.2 BLOOD

Blood carries substances such as nutrients and oxygen to all body's cells and transport waste product away from those same cells. In vertebrates, the blood composed of blood cells suspended in a liquid called volume blood plasma. 55% of blood fluids content in plasma,90% by volume mostly water, and contains dissolved proteins, glucose, mineral ions, hormones, carbon dioxide (plasma being the main medium for excretory product transportation), platelets and blood cells themselves. Blood cells have two types which are red blood cells and white blood cells, including leukocytes and platelets (also called thrombocytes).The most abundant cells in vertebrate blood are red blood cells. Hemoglobin, an iron containing protein, will help in increasing the transportation of blood oxygen by reversibly binding to this respiratory gas and increasing solubility in blood. Carbon dioxide will dissolved in plasma as bicarbonate ion for transport out the body. Vertebrate blood is bright-red when its hemoglobin is oxygenated.

Some animals use hemoglobin to carry oxygen, instead of hemoglobin such as crustaceans and mollusks. A fluid called hemolymph, have been used by insect and some mollusks instead of blood, the difference being that hemolymph is not contain in a closed circulatory system. Most insects use hemolymph does not contain oxygen-carrying molecules because of their size of their body is too small enough. Jawed vertebrates have an adaptive immune system, based largely on white blood cells. Infections and parasites will be resisting by white blood cells. Platelets are important in the clotting of blood. Hemolymphs which use by arthropods have hemocytes as their immune system. The pumping action by heart make the blood circulated around the body through blood vessels. Arterial blood in animal which have the lungs carries oxygen from inhaled air to the tissues of the body and venous blood carries carbon dioxide, a waste product of metabolism produced by cells, from the tissues to the lungs to be exhaled.

Blood performs many important functions within the body including supply oxygen to the tissues. It also supply of nutrients such as glucose, amino acids and fatty acids. Fatty acids dissolved in the blood or bound to plasma proteins for example blood lipids. Blood also function as removal of waste such as carbon dioxide, urea and lactic acid. Besides that, blood function as well as regulation of core body temperature. Then, it can be hydraulics functions in our body.

1.3 BLOOD VESSEL

These are the part of circulatory system that transports blood throughout the body. Blood vessel have three major types: arteries, the capillaries, which enable the actual exchange of water and chemicals between the blood and the tissues; and the veins, which carry blood from the capillaries back towards the heart.

1.3.1 Blood vessel disease

Peripheral vascular disease or artery disease is related to the blood vessel disease. This type of disease is about blood vessel in the abdomen, legs and arms. When the blood vessels narrow, less oxygen-rich blood gets to your body parts. This can cause tissue and cell death or gangrene. This disease is the leading cause of amputations. The cause of this disease appears when a build-up of fatty deposits called plague. Otherwise, the blood vessel or blood clots can cause other problems.

1.3.1.1 Signs of Blood Vessel Disease

Blood vessel disease also have a sign to show that a person might get it.First,the person will have muscle pain, aches or cramps on their body.Second,they will get cool, pale skin, cold both of their hands and feet.Third,the symptom is the person will get reddish-blue colour of the skin and nails of the hands and feet. Other symptoms is a sore that takes a long time to heal or scabbed over.Then, they loss of their hair on legs, feet or toes.Lastly, they will get faint or no pulse in the legs or feet.

1.3.1.2 Risk factors

All human being will get the blood vessel disease if cannot keep body healthy.A person is at higher risk for blood vessel disease if they are smoking. This habit will make their lungs and also the blood vessel worst. People who have diabetes also get a high risk to get this blood vessel disease. Then, people who are over 45 and have high cholesterol and blood pressure also open with this disease. Other risk peoples to get this disease are people who are overweight and inactive.

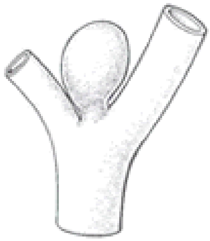
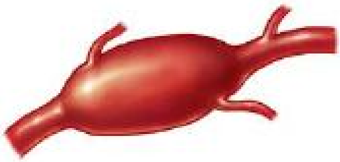
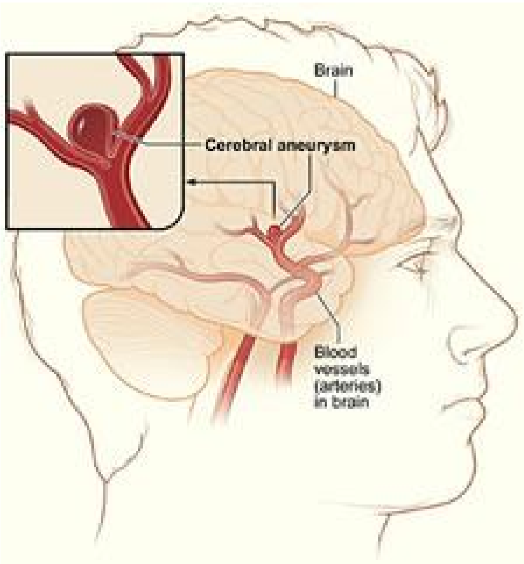
1.3.2 Anatomy

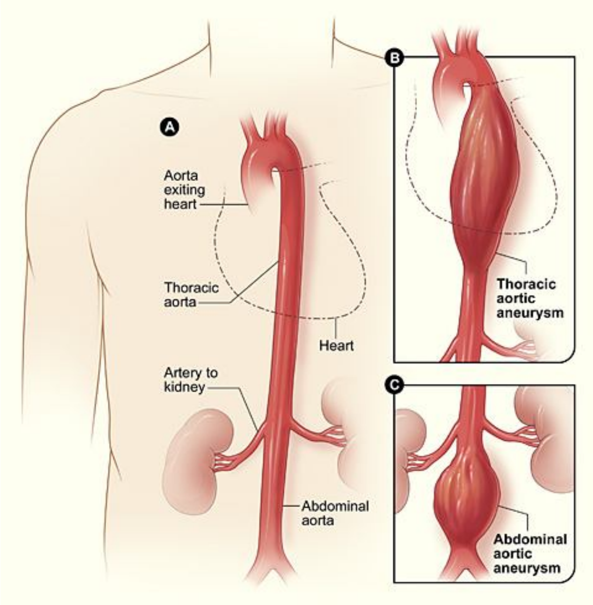
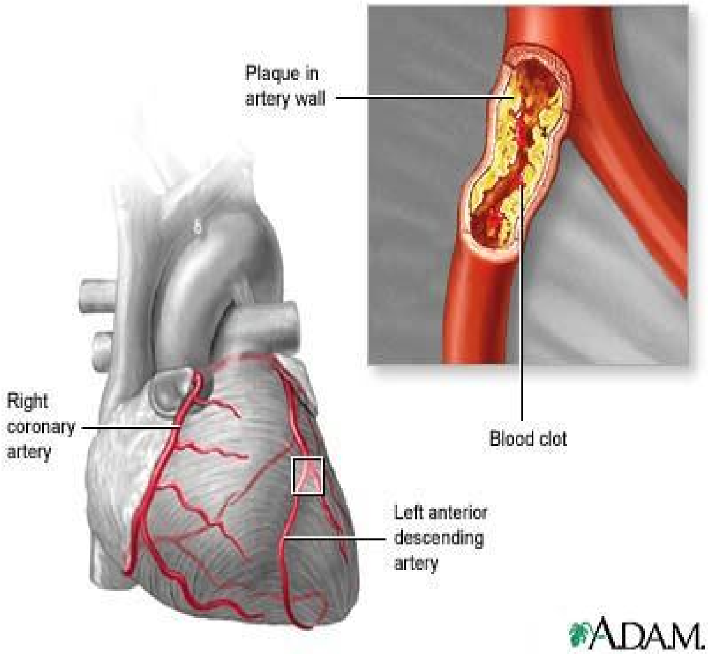
The arteries and veins have the same basic structure. There are three layers, from inside to outside while the capillaries have only one thick cell:

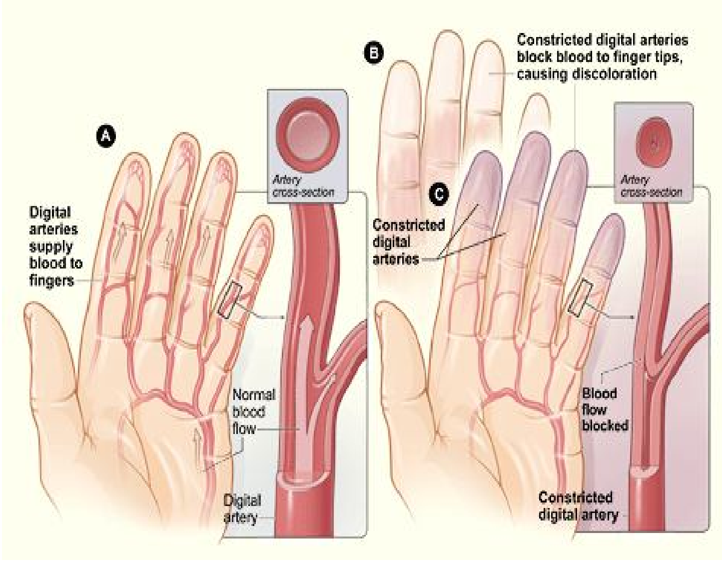
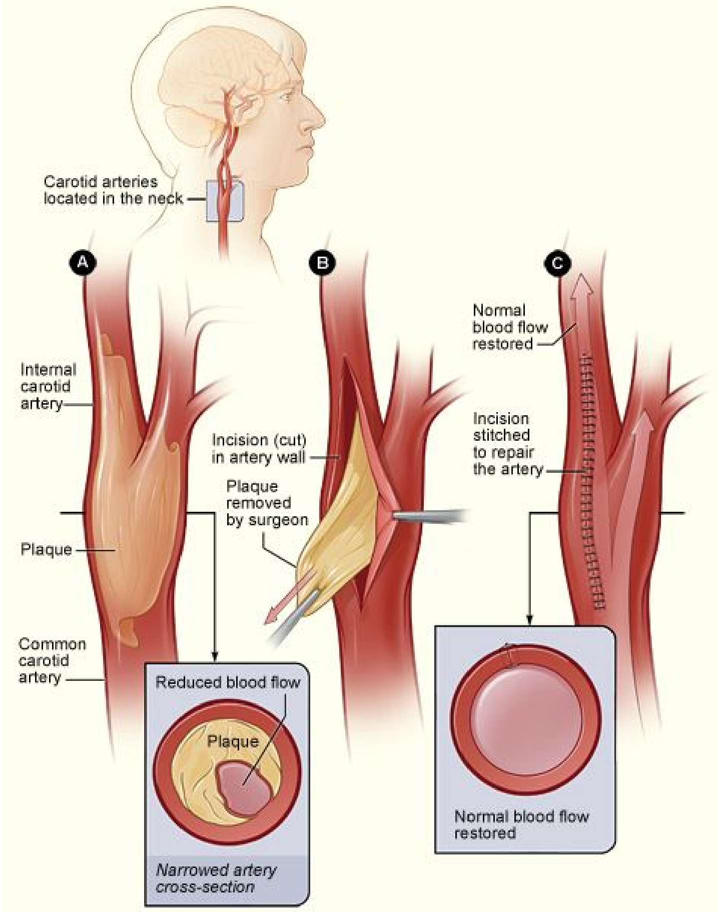
- *Tunica intima* (the thinnest layer): a single layer of simple squamous endothelial cells glued by a polysaccharide intercellular matrix, surrounded by a thin layer of sub endothelial connective tissue interlaced with a number of circularly arranged elastic bands called the *internal elastic lamina*.
- *Tunica media* (the thickest layer): circularly arranged elastic fiber, connective tissue, polysaccharide substances, the second and third layer are separated by another thick elastic band called external elastic lamina. The tunica media may (especially in arteries) be rich in vascular smooth muscle, which controls the caliber of the vessel.
- *Tunica adventitia*: entirely made of connective tissue. It also contains nerves that supply the muscular layer, as well as nutrient capillaries (vasa vasorum) in the larger blood vessels.

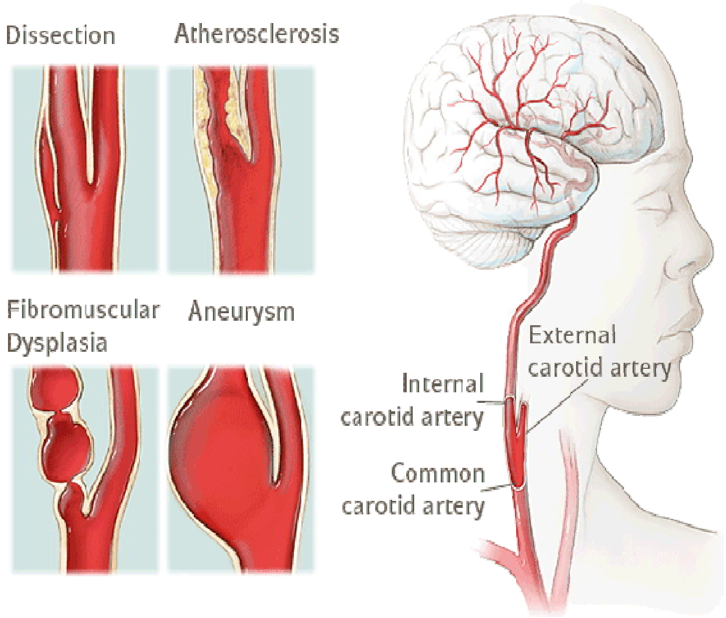
Capillaries consist of little more than a layer of endothelium and occasional connective tissue. When blood vessels connect to form a region of diffuse vascular supply it is called an anastomosis (pl. anastomoses). Anastomoses provide critical alternative routes for blood to flow in case of blockages.Laid end to end all the blood vessels in an average human body would encircle the earth twice, a distance of approximately 100,000 kilometers.

Table 1.1 Table of blood vessel diseases

Name of the disease	Picture
Aneurysm: a)Saccular aneurysm (Source:www.daviddarling.info)	
b)Fusiform aneurysm (Source:www.daviddarling.info)	
c)Cerebral aneurysm (Source:www.inventorspot.com)	

d)Aortic aneurysm (Source:www.inventorspot.com)	
Coronary artery disease (Source:www.adam.about.com)	

Raynauld disease (Source:www.vascularweb.org)	
Carotid disease (Source: www.nhlbi.nih.gov)	

Carotid Disease (Source: www.nhlbi.nih.gov)	

1.4 BLOOD FLOW PROFILE AT THE BRANCHES

Blood flow in arteries is dominated by unsteady flow phenomena. A nondimensional frequency parameter, the Womersley number, governs the relationship between the unsteady and viscous forces. Normal arterial flow is laminar with secondary flows generated at curves and branches. The arteries are living organs that can adapt to and change with the varying hemodynamic conditions. In certain circumstances, unusual hemodynamic conditions create an abnormal biological response. Velocity profile skewing can create pockets in which the direction of the wall shear stress oscillates. Atherosclerotic disease tends to be localized in these sites and results in a narrowing of the artery lumen stenosis. The stenosis can cause turbulence and reduce flow by means of viscous head losses and flow choking. Very high shear stresses near the throat of the stenosis can activate platelets and thereby induce thrombosis, which can totally block blood flow to the heart or brain. Detection and quantification of stenosis serve as the basis for surgical intervention.